

Chapter 7 GPS Survey Equipment

7-1. GPS Receiver Selection

Selection of the right GPS receiver for a particular project is critical to its success. To ensure success, selection must be based on a sound analysis of the following criteria: applications for which the receiver is to be used, accuracy requirements, power consumption requirements, operational environment, signal processing requirements, and cost. This chapter presents only a brief overview on GPS survey equipment and selection criteria. Prior to initiating procurement, USACE Commands are advised to consult the referenced guide specifications for procuring GPS equipment.

a. Receiver applications. Current USACE receiver applications include land-based, water-based, and airborne applications. Land applications include surveying, geodesy, resource mapping, navigation, survey control, boundary determination, deformation monitoring, and transportation. Water or marine applications include navigation and positioning of hydrographic surveys, dredges, and drill rigs. Airborne applications include navigation and positioning of photogrammetric-based mapping. Generally, the more applications a receiver must fulfill, the more it will cost. It is important for the receiver application to be defined in order to select the proper receiver and the necessary options.

b. Accuracy requirements. A firm definition of the accuracy requirements (e.g., point accuracy to 100 m, 50 m, 25 m, 5 m, 1 m, cm or mm) helps to further define procedure requirements (static or kinematic), signal reception requirements (whether use of C/A- or L1/L2 P-codes is appropriate), and type of measurement required (pseudo-range or carrier beat phase measurements). This is an important part in the receiver selection process.

c. Power requirements. The receiver power requirements are an important factor in the determination of receiver type. Receivers currently run on a variety of power sources from A/C to 12-volt car batteries or small camcorder batteries. A high end GPS receiver can operate 3 to 4 hr on a set of batteries, whereas a low end may operate 1 to 2 days on the same set.

d. Operational environment. The operational environment of the survey is also an important factor in the selection of antenna type and mount, receiver dimension

and weight, and durability of design. For example, the harsher the environment (high temperature and humidity variability, dirty or muddy work area, etc.), the sturdier the receiver and mount must be. The operational environment will also affect the type of power source to be used.

e. Processing requirements. Operational procedures required before, during, and after an observation session are very manufacturer-dependent and should be thoughtfully considered before purchase of a receiver. Often, a receiver may be easy to operate in the field, requiring very little user interface, but a tremendous amount of time and effort may be required after the survey to download the data from the receiver and process it (i.e., post-processing software may be complicated, crude, or under-developed). Also, whether a post-processed or real-time solution is desired represents a variable that is critical in determining the type of receiver to use.

f. Cost. Cost is a major factor in determining the type of receiver the user can purchase. Receiver hardware and software costs are a function of development costs, competition among manufacturers, and product demand. Historically, costs for the acquisition of GPS equipment have steadily fallen to the current range of prices seen today. High end receivers are upwards of \$35,000 down to a low end receiver of \$500.

g. Data exchange formats. In receiver selection it is important to remember that there is currently no standard format for exchanging data from different types of GPS receivers. However, most GPS receiver data can be put into a common text format such as RINEX. Refer to paragraph 7-4 for further discussion on receiver formats.

h. USACE. For most USACE civil applications, continuous tracking, C/A-code, L1 tracking, multichannel (eight or more channels) receivers are adequate. Receivers with other features may be required for a particular application. For example, a dual frequency (L1/L2) receiver with the cross correlation, squaring, or some other technique during anti-spoofing is required for the OTF and rapid static surveying techniques.

7-2. Conventional GPS Receiver Types

There are two basic types of GPS receivers: code phase and carrier phase receivers. Within these types there are C/A- and P-code receivers, codeless receivers, single- and dual-frequency receivers, and receivers that use cross correlation or squaring or P-W techniques. Figure 7-1 shows common equipment required at a station.



Figure 7-1. Common GPS equipment required at each setup

a. Code phase receivers. A code receiver is also called a “code correlating” receiver because it requires access to the satellite navigation message of the P- or C/A-code signal to function. This type of receiver relies on the satellite navigation message to provide an almanac for operation and signal processing. Because it uses the satellite navigation message, this type of receiver can produce real-time navigation data. Code receivers have “anywhere-fix” capability and, consequently, a quicker start-up time at survey commencement. An anywhere-fix receiver has the unique capability to begin calculations without being given an approximate location and time. A code receiver has anywhere-fix capability because it can synchronize itself with GPS time at a point with unknown coordinates once lock on the signals of four satellites has been obtained.

b. Carrier phase receivers. A carrier phase receiver utilizes the actual GPS signal itself to calculate a position. There are two general types of carrier phase receivers: (1) single frequency and (2) dual frequency.

(1) Single-frequency receivers. A single-frequency receiver tracks the L1 frequency signal. The single-frequency receiver generally has a lower price than the dual-frequency receiver because it has fewer components and is in greater demand. A single-frequency receiver can be used effectively to develop relative positions that are accurate over baselines of less than 50 km or where ionosphere effects can generally be ignored.

(2) Dual-frequency receivers. The dual-frequency receiver tracks both the L1 and L2 frequency signal. A dual-frequency receiver is generally more expensive than a single-frequency receiver. A dual-frequency receiver will more effectively resolve longer baselines of more than 50 km where ionosphere effects have a larger impact on calculations. Dual-frequency receivers eliminate almost all ionosphere effects by combining L1 and L2 observations. Most manufacturers of dual-frequency receivers utilize codeless techniques which allow the use of the L2 during anti-spoofing. These codeless techniques are squaring, cross-correlation, and P-W correlation.

(a) Squaring. Receivers which utilize the squaring technique are only able to obtain one-half of the signal wavelength on the L2 during anti-spoofing and have a high 30-dB loss.

(b) Cross correlation. Receivers that use this technique have a high 27-dB loss but are able to obtain the full wavelength on the L2 during anti-spoofing.

(c) P-W correlation. This method allows for both a low 14-dB loss and full wavelength on the L2 during anti-spoofing.

c. Military grade GPS receivers. The current military GPS receiver is the precise lightweight GPS receiver (PLGR), AN/PSN-11, which uses the course/acquisition (C/A), precise (P), or encrypted P(Y) codes. PLGR is designed to operate as a stand-alone unit and provide navigation information: position, velocity, and time. PLGR requires a crypto key to operate as a PPS receiver. A PPS receiver corrects for errors introduced by selective availability (S/A) and cannot be spoofed by imitated or retransmitted GPS signals, anti-spoofing (A/S). The accuracy is 16-m SEP when keyed. PLGR does not record code data because it was designed to be a navigation device, and P-code data are classified at time of reception. This also limits PLGR’s ability to be used in differential GPS. PLGR can only be used in differential GPS when using C/A code and as a rover unit. However, C/A code differential GPS is not authorized by DoD for tactical military operations. If high accuracy surveys are required during a military conflict, PPS geodetic GPS receivers are available through commercial manufacturers. PLGRs or PPS receivers are the only authorized receivers to be used in a conflict area.

(1) Non-military DoD organizations that need PLGR accuracy for their positioning requirements can purchase

PLGR from the existing DoD contract through a memorandum of agreement with DoD.

(2) Commercial GPS receiver manufacturers produce hand-held, low cost PPS GPS receivers capable of 16-m SEP accuracy when keyed. These receivers may or may not have anti-spoofing capability and require the same crypto keys as PLGR.

7-3. Receiver Manufacturers

Up-to-date listings of manufacturers are contained in various surveying trade publications. Contact should be made directly with representatives of each firm to obtain current specifications, price, availability, material, or other related data on their products.

7-4. Other Equipment

There are several other relative miscellaneous equipment items that should be considered when making a GPS receiver selection. This equipment is discussed below.

a. Data link equipment for real-time positioning. The type of data link needed for real-time positioning should be capable of transmitting digital data. The specific type of data link will depend on the user's work area and environment. Most manufacturers of GPS equipment can supply or suggest a data link that can be used for real-time positioning. Depending on the type and wattage of the data link, a frequency authorization may have to take place in order to transmit digital data. Some radio and GPS manufacturers produce 1 W or less radios for transmission of digital data which do not require frequency authorization.

b. U.S. Coast Guard (USCG) radiobeacon receivers. The USCG provides a real-time pseudo-range corrections broadcast over low frequency (270-320 kHz marine band) from a radiobeacon transmitter tower. These towers exist in most if not all coastal areas including the Mississippi River and the Great Lakes regions. The range from each tower is approximately 120 to 300 km. These corrections can be received by using a radiobeacon receiver and antenna tuned to the nearest tower site. For further information on this system contact the USCG office in your district or the number listed in Appendix C.

c. Computer equipment. Most manufacturers of GPS receivers include computer specifications needed to run their downloading and post-processing software. Most software can be run on a 386-type computer with a math co-processor or on a 486-type computer.

d. Antenna types. There are three basic types of GPS antennas: ground plane antennas, no ground plane, and choke ring antennas. Both the ground plane and the choke rings are designed to reduce the effects of multipath on the antenna.

e. Associated survey equipment. There are several accessories needed along with a GPS receiver and antenna. These include tripods, tribrachs, and tribrach adapters to name a few. Fixed height (usually 2 m) poles can be used to eliminate the need to measure antenna heights. Most of the other equipment needed is similar to what is used in a conventional survey.

7-5. GPS Common Exchange Data Format

a. RINEX. Receiver INdependent EXchange (RINEX) format is an ASCII-type format which allows a user to combine data from different manufacturer's GPS receivers. Most GPS receiver manufacturers supply programs to convert raw GPS data into a RINEX format. However, one must be careful since there are different types of RINEX conversions. Currently, the NGS distributes software which converts several receivers' raw GPS data to RINEX. NGS will distribute this software free of charge to any government agency.

b. Real-time data transmission formats. There are two types of common data formats used most often during real-time surveying: (1) RTCM SC-104 v. 2 and (2) NMEA.

(1) Transmission of data between GPS receivers. The Radio Technical Commission for Maritime Services (RTCM) is the governing body for transmissions used for maritime services. The RTCM Special Committee 104 (SC-104) has defined the format for transmission of GPS corrections. The RTCM SC-104 standard was specifically developed to address meter-level positioning requirements. This current standard transmission standard for meter-level DGPS is the RTCM SC-104 v. 2.0. This standard allows various manufacturers' equipment to work together if it is used at both the reference and remote stations. It should be noted that not all manufacturers fully support the RTCM SC-104 v. 2.0 format, and careful consideration should be made to choose one that does. A committee was formed to address the means of a transmission format for centimeter-level DGPS. This committee proposed the RTCM SC-104 v. 2.1 format, which supports raw carrier phase data, raw pseudo-range data, and corrections for both. This will allow for correction of ionosphere and troposphere errors, with dual frequency measurements, to be applied at the receiving station. It is

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deemed to be downward compatible with RTCM SC-104 v. 2.0, and therefore no special transmission considerations need to be made to use it.

(2) Transmission of data between a GPS receiver and a device. The *National Maritime Electronics Association (NMEA)* governs the format of output records (i.e., the positions at the remote end). The standard concerning the

corrected GPS output records at the remote receiver is referred to as the *NMEA 0183 Data Sentencing Format*. The NMEA 0183 output records can be used as input to whatever system the GPS remote receiver is interfaced. For example, GPS receivers with an NMEA 0183 output can be used to provide the positional input for a hydrographic survey system or an Electronic Chart Display and Information System (ECDIS).